Effect of diet and age on breast muscle characteristics in commercial broilers

Non- Honors Research Thesis

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Table of Contents

Abstract

In recent years, the poultry industry has been challenged with a series of anomalies in the pectoralis major breast muscle which are associated with negative meat quality traits including increased cook loss, increased toughness, and an overall poor eating experience. It is estimated that these conditions cost the poultry industry >$200M/year. It is believed by most poultry and meat scientists that the rapid growth rate and increase in market weight in modern broilers are contributing factors to these problems. To better understand the factors underlying muscle growth and optimal processing traits, we investigated the effects of diet and age on muscle growth in Ross-708 male broilers grown to 9-weeks of age. Day-old chicks (n=200) were randomly assigned to eight pens (1 sq. ft/bird). All birds were *ad libitum* fed from 0 to 14 d. From 14 to 63 d, half the pens continued to be *ad libitum* fed while the other half were restrict fed to 80% *ad libitum* intake. Bodyweight and feed intake of each pen was measured weekly. Beginning at 14 d, 3 birds/pen were randomly selected and harvested weekly. Qualitative breast muscle data (weight, depth at the cranial end, tenderness) was also collected weekly from 14 d through the end of the study. Feed-restriction reduced average bodyweight and breast muscle depth from 28 to 63 d (P < 0.05). From 42 to 63 d, the breast muscle toughness of *the ad libitum* fed birds was significantly greater than the restrict fed birds (P< 0.05). Therefore, the data suggests that some degree of feed restriction may improve qualitative aspects of broiler breast muscle.

Introduction

Overview

The United States is the second largest consumer of poultry meat and meat products in the world. Per capita consumption exceeds 90 pounds, annually (National Chicken Council, 2017) which is greater than that for beef or pork. Such poultry-meat popularity is a function of personal preference, tradition, religious reasoning, affordability, health perception, and the introduction to further processed products (Barbut, 2016). Consequently, more than 9 billion broilers were produced last year, and poultry consumption is projected to increase in the future (National Chicken Council, 2017). To meet this demand, generations of broiler chickens have been continuously selected for overall increased size and market weight (**Figure 1**), as well as increased growth rate (**Figure 2**).

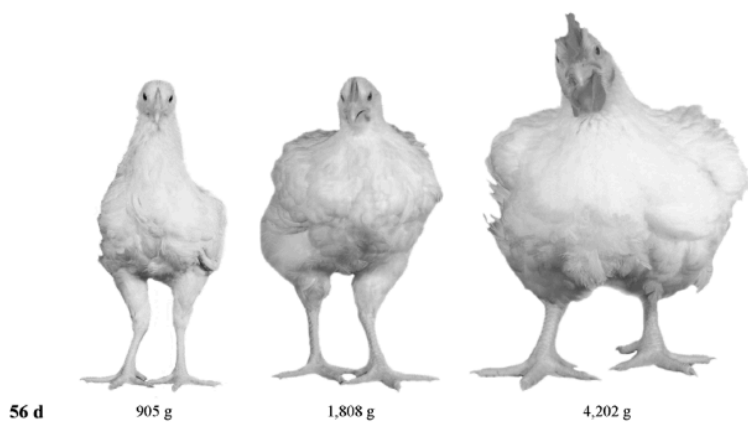

Figure 1: Apparent size and weight difference of 56-day-old University of Alberta Meat Control broiler strains unselected since 1957, 1978, and 2005 (Zuidhof *et al*., 2014).

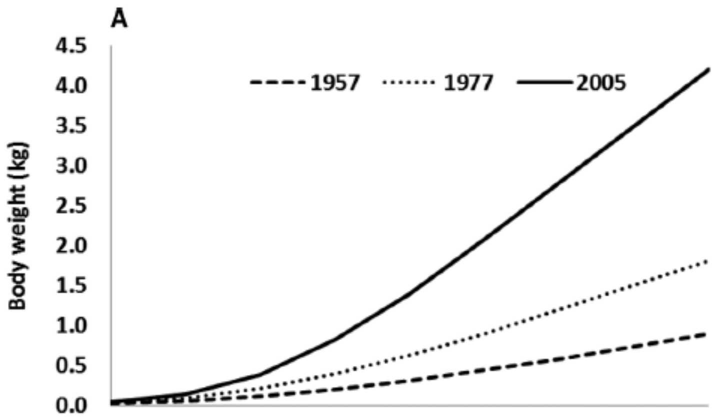

Figure 2: Absolute bodyweight of mixed sex University of Alberta Meat Control broiler strains unselected since 1957, 1978, and 2005 (Zuidhof *et al.*, 2014).

With increased breast yield and market weight (Zuidhof *et al.*, 2014), however, the poultry industry has recently been challenged with a greater incidence of muscular anomalies, known as myopathies, observed in the pectoralis major breast muscle. Myopathies in the breast result in decreased meat quality traits, including increased cook loss, decreased tenderness, and an overall poor eating experience (Mudalal *et al.*, 2015). Two of the most prominent myopathies in the poultry industry are woody breast (WB), which is characterized as the hardening or toughening of the breast muscle, and white striping (WS), which is characterized as white striations in the breast tissue, parallel to the muscle fibers.

Background

Much research has been conducted on the WB and WS phenomena (Kuttappan *et al.,* 2012; Kuttappan *et al.,* 2013a; Kuttappan *et al.,* 2013b; Russo *et al.,* 2015; Shivo *et al.,* 2014; and Tijare *et al.,* 2016). Poultry affected by this myopathy have a tough, bulging, and pale breast muscle (**Figure 3**). It is associated with heavier bodyweights (Kuttappan *et al.,* 2013b). Histologically, muscle degeneration, regeneration, fiber necrosis, immune cell infiltration, and collagen deposition are seen with this condition and increase with severity (Velleman and Clark, 2015). Sarcomeres also tend to increase in length along with the severity of this condition (Tijare *et al.,* 2016).

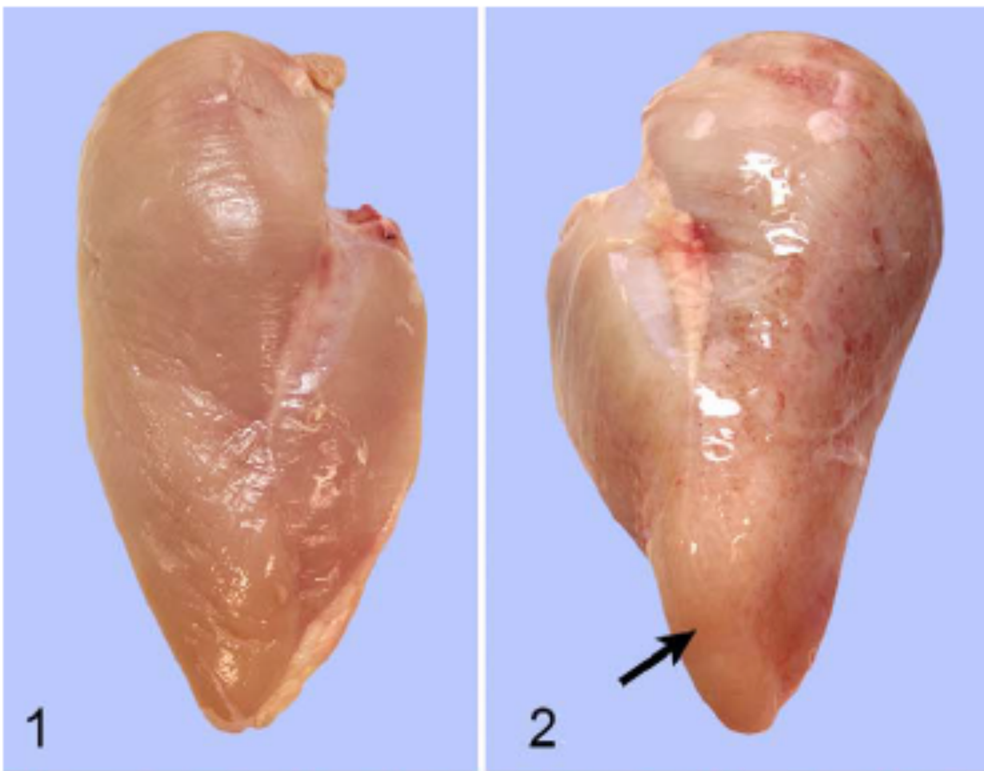

Figure 3: *Normal breast (1) compared to wooden breast (2) (Shivo et al., 2014).*

White striping often accompanies WB; however this is not always the case. With WS, white striations are observed, running parallel to the muscle fibers. Like WB, WS exhibits varying degrees of severity (**Figure 4**). Breast fillets exhibiting varying degrees of WS also exhibit variation in chemical composition. Fat concentration is greater, while protein concentration is lower in chicken breasts exhibiting high severity of WS (Kuttappan *et al.,* 2012). Microscopically, fillets with this myopathy are identified with multiple stages of development, myodegeneration, regeneration, necrosis, and adipose tissue infiltration

(Russo *et al.,* 2015). Similarly to WB, the condition of WS has also been shown to increase in severity with increased body weight (Kuttappan *et al.*, 2013b).

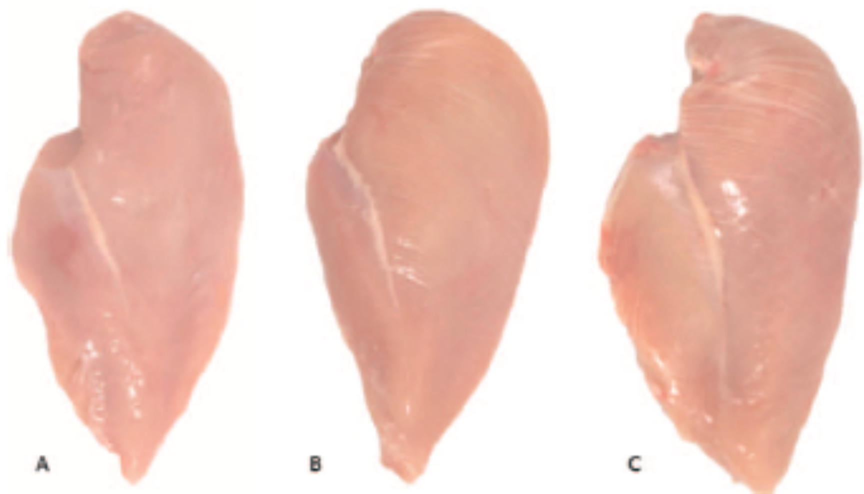

Figure 4: A ➔ B➔ C shows progression of macroscopic changes associated with growth, negatively impacting meat quality (Kuttappan *et al.*, 2013).

Meat Quality and Palatability

WB demonstrates poor palatability, as the meat can be very tough, almost like wood. Breasts exhibiting both WB and WS characteristics have been shown to demonstrate decreased water holding capacity, tougher meat, and less juiciness. These are all considered poor meat quality attributes which are not preferred by the majority of US consumers. It is estimated that these conditions cost the poultry industry in excess of $200M each year (Kuttappan *et al.*, 2016).

Objectives and Hypothesis

It is generally accepted by most poultry and meat scientists that the rapid growth rate and increase in market weight of modern broilers are contributing factors to these problems (Kuttappan *et al., 2012;* Mazzoni *et al.*, 2015; Petracci *et al.*, 2013; Shivo *et al.*, 2014). To further investigate these conditions associated with poor meat quality, we proposed to restrict feed intake to slow muscle growth. In doing so, we hypothesized that meat quality characteristics would be improved.

Materials and Methods

Treatments and on-farm data collection

Day-old Ross-708 male chicks (n=200) were randomly assigned to one of eight pens (25 birds per pen; 1 sq. ft/bird) across two rooms. All birds were fed an *ad libitum* corn-soy diet (**Table 1**) from 0 to 14 d. From 14 to 63 d, half the pens continued to be fed *ad libitum* (CNT), while the other half were restrict fed to 80% *ad libitum* intake (RES). All other husbandry and housing conditions (*ad libitum* water, lighting schedule, litter depth, etc.) were maintained across pens. Bodyweight and feed intake were measured weekly. Bird mortality and culling were recorded throughout the duration of the study.

Table 1: Composition of corn-soy broiler diet used through duration (d0 to d63) of study

Ingredient	% Composition
Ground Corn	58.250
Soybean Meal, 48%	33.800
Blended Fat	4.100
Dicalcium phosphate, 18.5%	1.500
Ground Limestone	1.100
Akey Turkey Starter Premix	0.500
Salt	0.440
DL-Methtionine	0.210
Choline Chloride	0.100

Bird sampling and qualitative muscle data collection

Beginning at 14 d, 3 birds/pen were randomly selected and slaughtered weekly using electrical stunning followed by exsanguination. Carcasses were immersed in ice water and chilled to <4˚C in ≤4 hours. Chilled carcass weights were obtained, and paired breasts (pectoralis major) were removed from each carcass and weighed individually. Each left breast was then vacuum packaged and frozen (-20˚C), whereas the right breast was further analyzed for qualitative data. Breast muscles were placed on a ruler grid and photographed. Breast dimensions (length & width) were measured in ImageJ (v.1.51). Breast depth was measured by hand using a caliper. All breasts were then bagged, sealed, and cooked to an internal temperature of 73.9°C and then immediately air chilled to an internal temperature of 4°C. Chilled, cooked breast samples were removed from bags and weighed for cook loss measurement. Shear force was obtained at 80% breast muscle depth using a TA.XT*plus* Texture Analyzer equipped with a blunt Meullenet-Owens Razor Shear (bMORS) blade (Yancey *et al.*, 2010). Shear energy (N*mm; "toughness") and shear force (N; "peak force") were measured across 4 positions on each breast fillet (**Figure 5**).

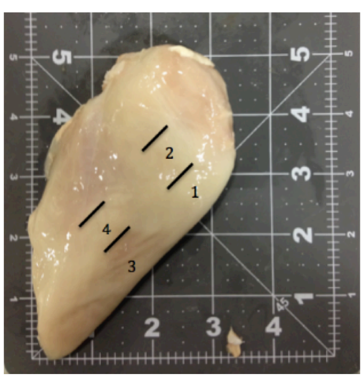

Figure 5: Measurements of toughness and shear force taken at labeled positions on fillet, using a TA.XT*plus* Texture Analyzer equipped with a blunt Meullenet-Owens Razor Shear (bMORS) blade.

Results

Bird Performance

Feed restriction was successfully reduced the growth rate and decreased live bodyweights in RES versus CNT birds (**Figure 6**); however there was no treatment effect on feed conversion ratio (FCR). The overall FCR for the study was 1.830 (+/- 0.041). Mortalities and culls were too few for statistical analysis. Numerical values for early (≤14d) and late (>14d) percent mortality, which include both mortalities and culls, were as follows: RES early mortality = 4.0%; RES late mortality = 7.1%; CNT early mortality = 4.0%; and CNT late mortality = 4.2%.

Figure 6: Growth curve of restrict fed (RES) and ad libitum fed (CNT) birds from 0 to 63 days of age. *Indicates significance at P <0.05

Qualitative Muscle Differences

Weights of the pectoralis major and pectoralis minor were successfully decreased by feed restriction. The weights of the pectoralis major muscles were significantly decreased in the RES birds from 42d to 63d (P <0.05). Pectoralis minor weights were significantly decreased in the RES birds from 35d to 63d (*P* <0.05). Breast dimensions were also measured; CNT birds were larger, wider, and thicker. Breast depth however was shown to have a significant day × diet interaction (**Figure 7**).

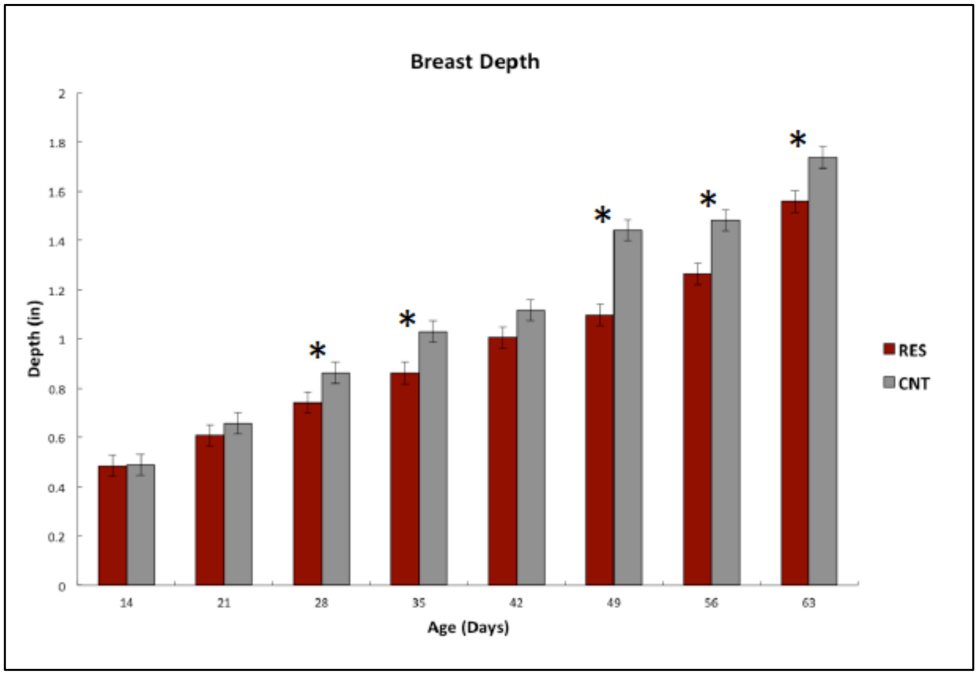

Figure 7: Breast muscle depth of restrict fed (RES) and ad libitum fed (CNT) birds from 14 to 63 days of age. *Indicates significance at P <0.05.

Toughness was shown to be significantly greater in CNT birds from 21d to 63d (**Figure 8**). Peak shear force average values were also analyzed, but did not exhibit a significant day × diet interaction. However, analysis within position revealed that the more distal cranial aspect (position 2 seen in **Figure 9**) of the breast exhibited a significant day × diet interaction (**Figure 9**). Breast weight and dimensions (length, width, and depth) were all positively correlated to toughness and peak shear force values (*P <0.0001*; data not shown), with breast depth exhibiting the strongest correlation for toughness (r = 0.95) and peak force (r = 0.65).

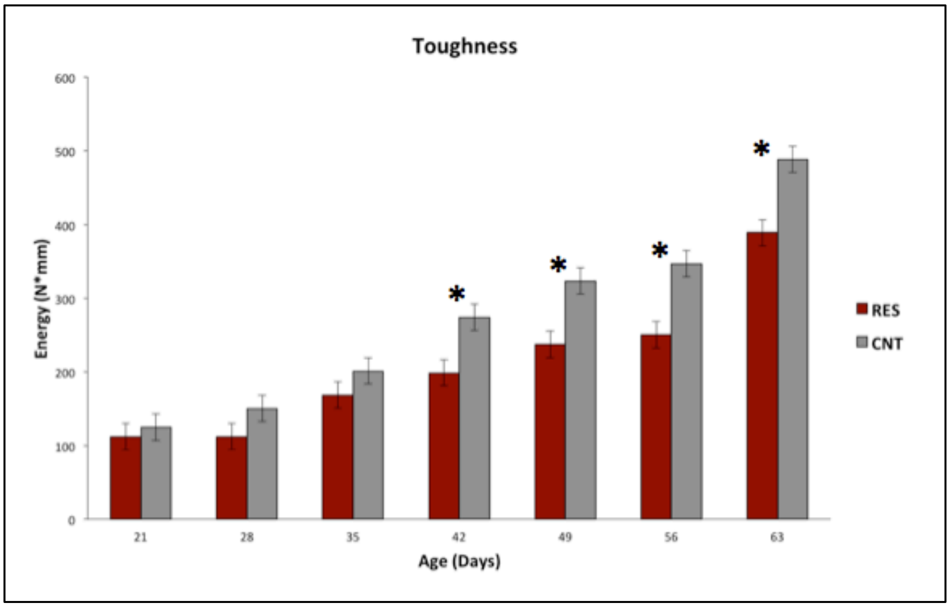

Figure 8: Toughness of breast muscle from restrict fed (RES) and ad libitum fed (CNT) birds from 21 to 63 days of age. *Indicates significance at P <0.05.

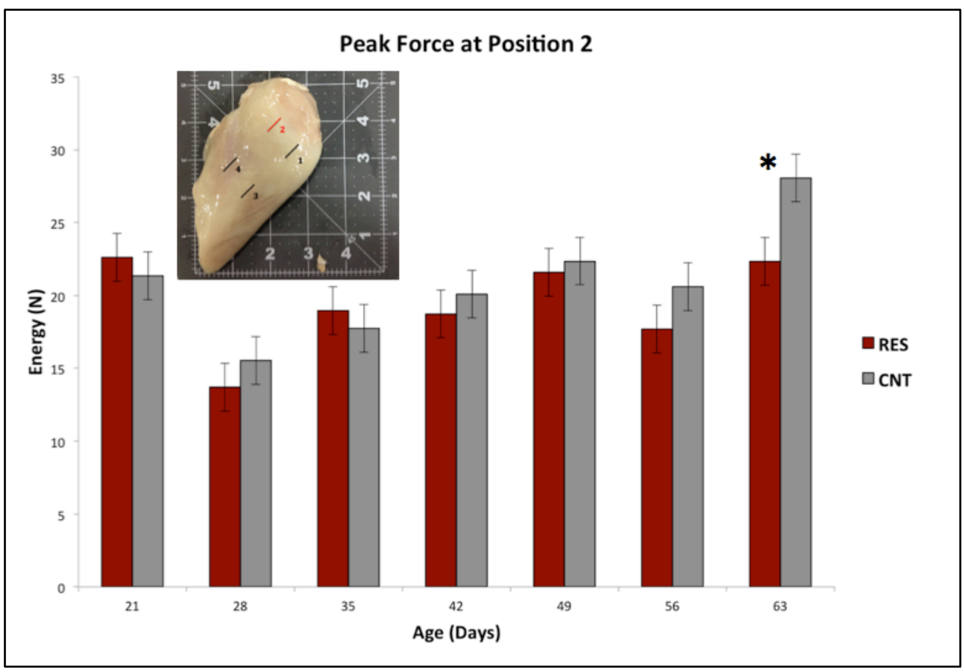

Figure 9: Peak shear force values taken at position 2 of breast muscle from restrict fed (RES) and ad libitum fed (CNT) birds from 21 to 63 days of age. *Indicates significance at P <0.05.

Discussion

This study showed that feed restriction slowed the growth rate and reduced the overall size of broiler chickens which in turn improved some aspects of breast meat tenderness during late production (42 to 63 days of age). Trocino *et al.* (2015) was also capable of reducing growth rate and bird size in broilers restrict fed (80% ad libitum) from 13d to 21d. They also observed greater shear force values in breasts classified as WB; however, they did not draw any conclusions that feed restriction reduced the incidence of WB or influenced shear force directly. It is important to note that this group only restrict fed from 13d to 21d, while we restrict fed from 14d to 63d. They also allowed for compensatory gain to occur after 21d until the time of slaughter (day 46). The birds in this study did not experience compensatory gain and were slaughtered at a later age (day 63) and larger ultimate size. With a longer (and more continuous) period of feed restriction, meat tenderness was observed, supporting our hypothesis that a higher body weight leads to more severe anomalies. We also found that breast weight decreased through feed restriction. Other studies have shown similar findings; heavier breast weights are associated with a higher severity of muscle myopathies (Kuttappan *et al.,* 2013). Along with this correlation, they also found that more fat and less protein are present in affected breasts.

Kuttappan *et al.,* (2013b) also found that breast yield increases with severity of the conditions. As stated before, genetic selection has had a large role in the poultry industry as we have been selecting for larger breasts and faster growing birds for several years. Therefore, with an increased weight and larger breast yield, there is a higher probability of more severe anomalies affecting the breast meat.

Other studies have shown that cook loss percentage increases significantly with an increase in severity of the myopathies (Kuttappan *et al.,* 2013; Petracci *et al.,* 2013b; and Tijare *et al.,* 2016). Many studies have also shown that marinated and non-marinated breasts have a higher cook loss percentage, especially non-marinated breasts (Tijare *et al.,* 2016). Cook loss is important to take into account when marketing to the consumer. Because cook loss is the shrinkage of the product during the cooking process, many consumers prefer to have a lower cook loss, as they will experience a juicier and more satisfying piece of meat once it is cooked. Along with increased cook loss, marinade up-take has also been shown to decrease with these myopathies (Petracci *et al.,* 2013b). This is also important for consumers to consider, as many prefer to marinate their meat. However if the marinade is not absorbed, the palatability decreases. If palatability (tenderness and juiciness) is lost, the consumer will make other purchasing decisions and potentially consume fewer poultry meat and meat products.

Kuttappan *et al.* (2013b) separated birds based on the severity of WS present in the breast and found that shear force values did not differ. However it was concluded that while there is a higher probability that greater WS is seen in heavier birds, WS specifically did not have any major effects on cooked meat quality. In our study, we observed that heavier birds yielded tougher meat, but we made no conclusions or observations concerning WS. CNT birds not only had higher weights, but also had higher shear force values than RES birds, resulting in a tougher breast. We also investigated the peak shear force at various positions within the pectoralis major. Our study showed that position 2, the more distal cranial portion of the breast, exhibited a significant day × diet interaction (**Figure 9**). Greater cranial thickness was also observed in this position of CNT birds, and also had the strongest correlation to toughness. From this data, we can infer that greater cranial thickness also influences poor meat quality. Kuttappan *et al.* (2013b) also support this evidence. In their study, birds with a higher severity of WS exhibited greater cranial thickness.

Overall, our findings are consistent with several studies, indicating that increased body weight and breast muscle depth have negative impacts on meat quality characteristics (Kuttappan *et al.*, 2013; Mudalal *et al*., 2014; 2015).

Conclusion

This study effectively decreased the growth rate and ultimate size of feed restricted commercial broilers. In doing so, we decreased breast muscle depth and shear force values, thus supporting our hypothesis that reducing the ultimate size of broilers has a beneficial impact on muscle integrity and resulting meat quality. The relationship between growth rate and meat quality aspects deserves further attention, as this study was unable to draw strong conclusions on the effect of growth rate on muscle health and meat quality. Additional studies in this area are necessary, as a greater understanding of breast muscle myopathies, such as WB and WS, could save the poultry industry millions of dollars, as well as improve the eating experience for consumers.

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